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(71) Applicant
Texas Instruments Incorporated, 13500 North Central Expressway, Dallas, Texas, United States of America

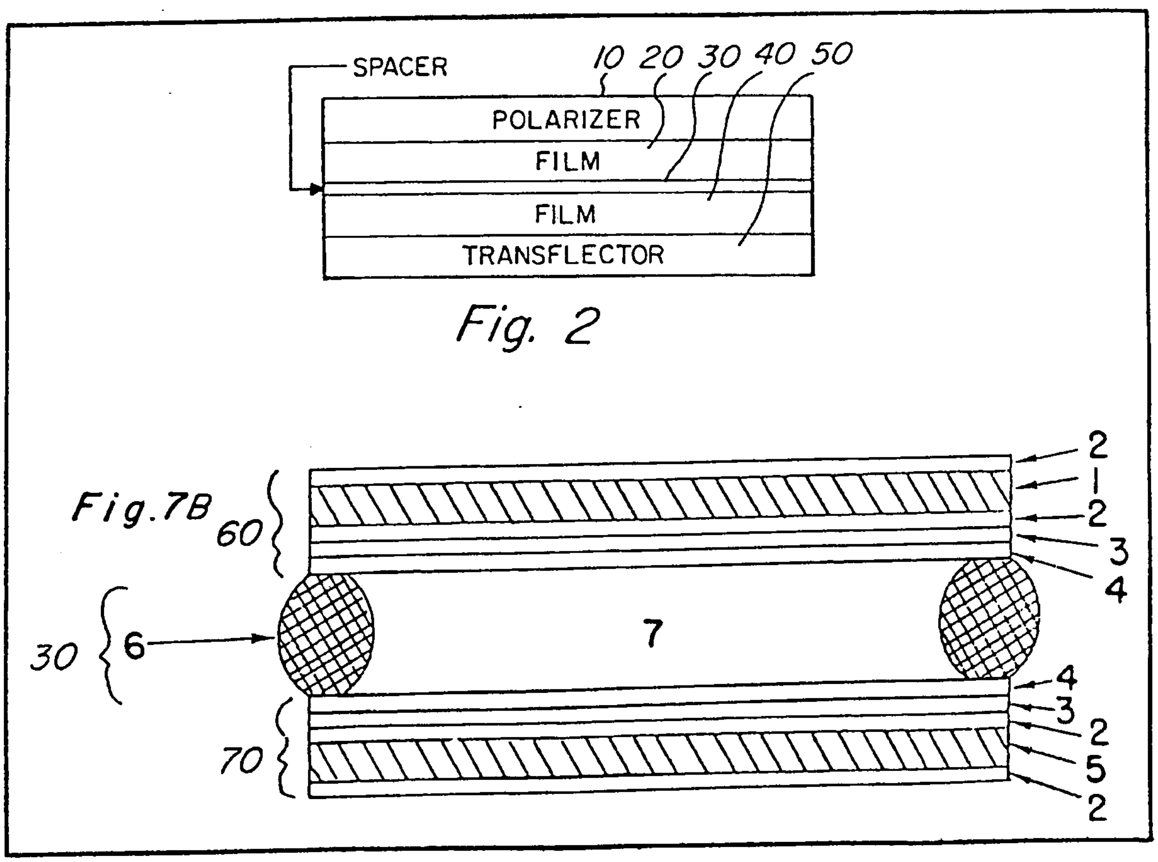
(72) Inventors
Bobby G. Culley,
Kishin Surtani,
Walter Y. Wen

(74) Agent
Abel & Imray

(54) Liquid Crystal Display Cell

(57) Liquid crystal material is contained between flexible electrode-bearing films 20, 40 which are coated with liquid crystal aligning layers and are spaced and sealed together by a ring 30 (the liquid crystal may contain additional spaces). Polarising films 10, 50, one of which may be transflective may be applied to respective films 20, 40, or, for labour and material saving, may provide the flexible films as in Fig. 7B — showing polarising film 1 between protective layers 2 and carrying conductors 3 and aligning layers 4. The cell may be made in a continuous process starting with reels of conductor-coated film.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.



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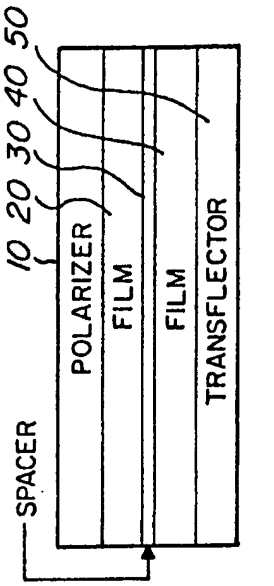


Fig. 2

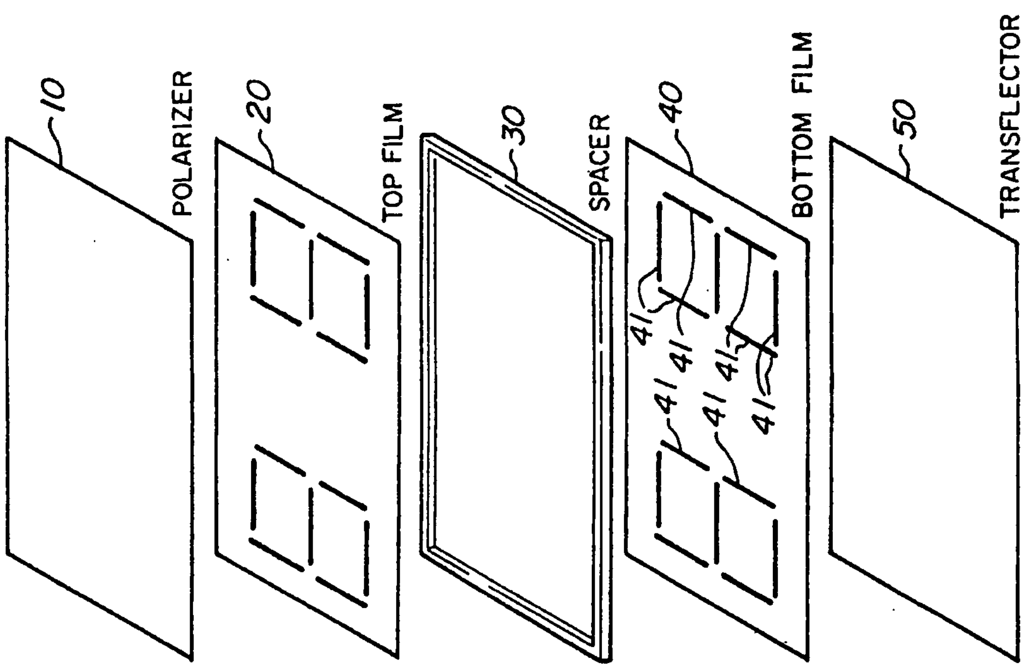
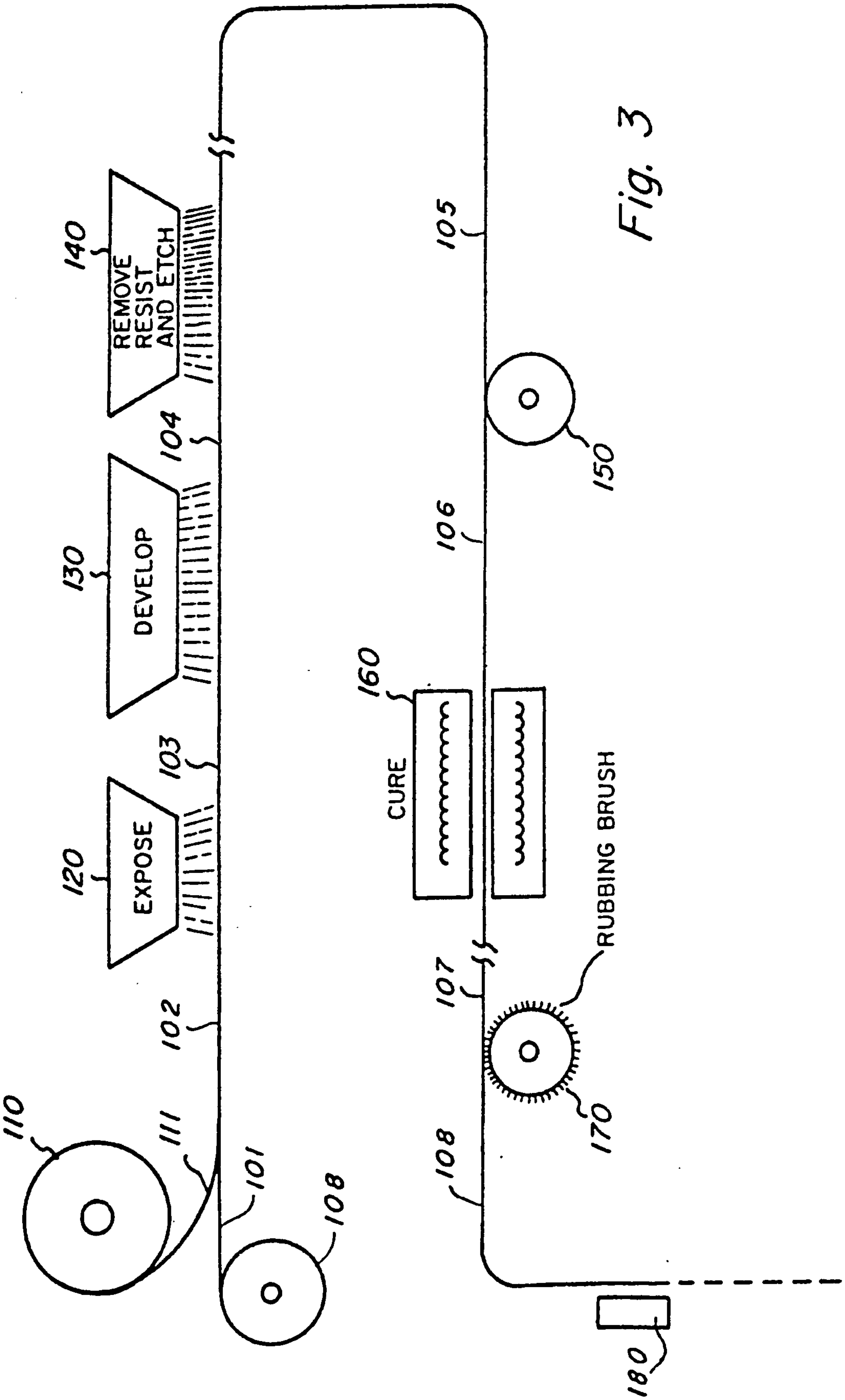


Fig. 1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111
101
108
102
120
EXPOSE
103
130
DEVELOP
104
140
REMOVE RESIST AND ETCH
105
150
106
160
CURE
RUBBING BRUSH
107
170
108
180

Fig. 3

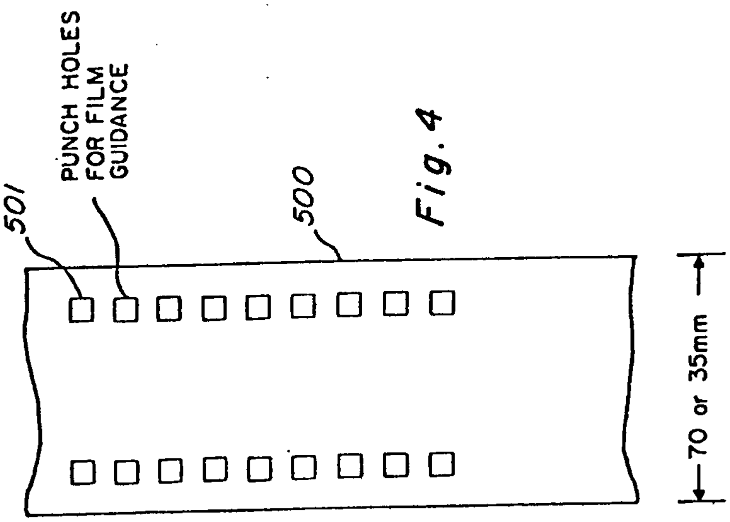

Fig. 4

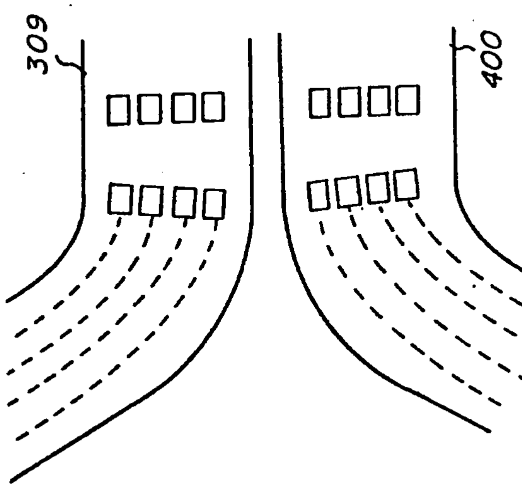

Fig. 9B

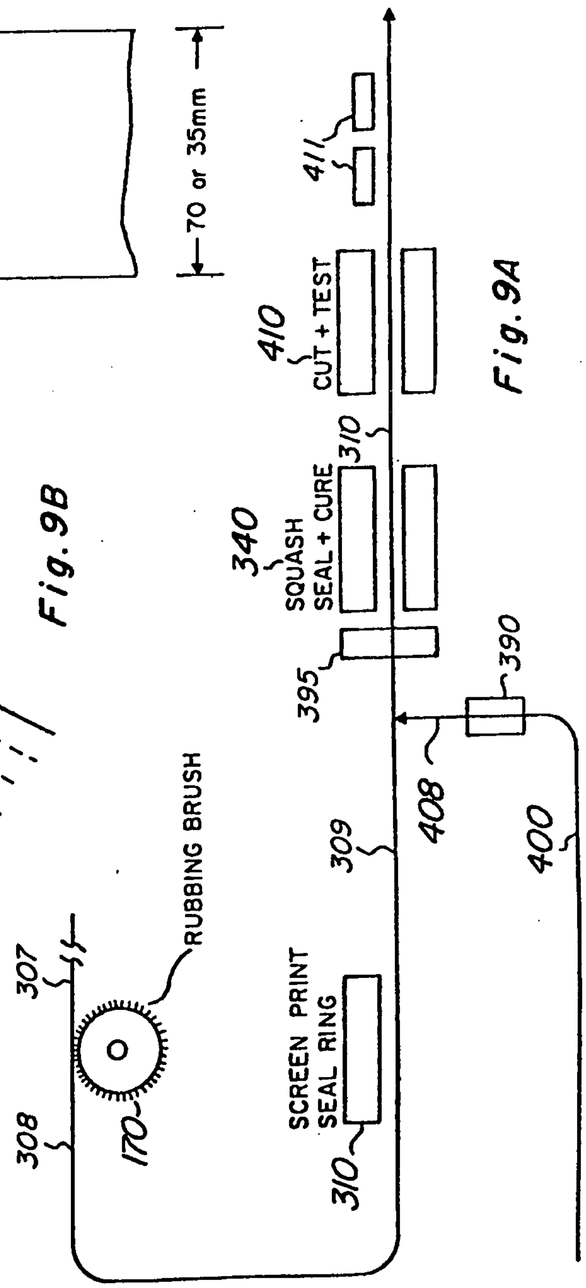

Fig. 9A

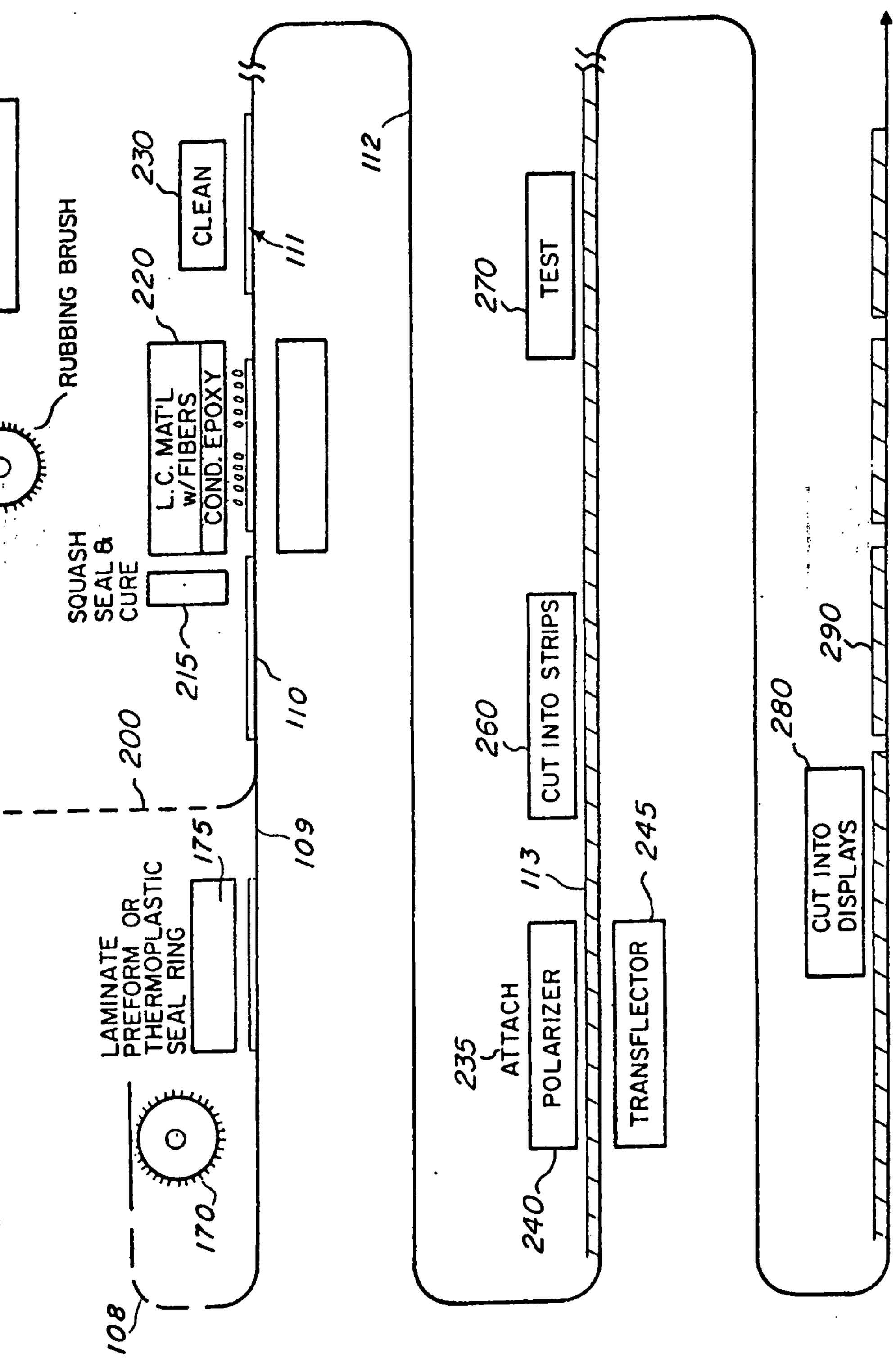
CURE
RUBBING BRUSH
230
CLEAN
220
L.C. MAT'L
W/FIBERS
COND. EPOXY
111
112
SQUASH
SEAL &
CURE
215
110
200
109
175
LAMINATE
PREFORM OR
THERMOPLASTIC
SEAL RING
170
108
235
ATTACH
POLARIZER
240
113
TRANSFLECTOR
245
270
TEST
260
CUT INTO STRIPS
290
280
CUT INTO
DISPLAYS

Fig. 5

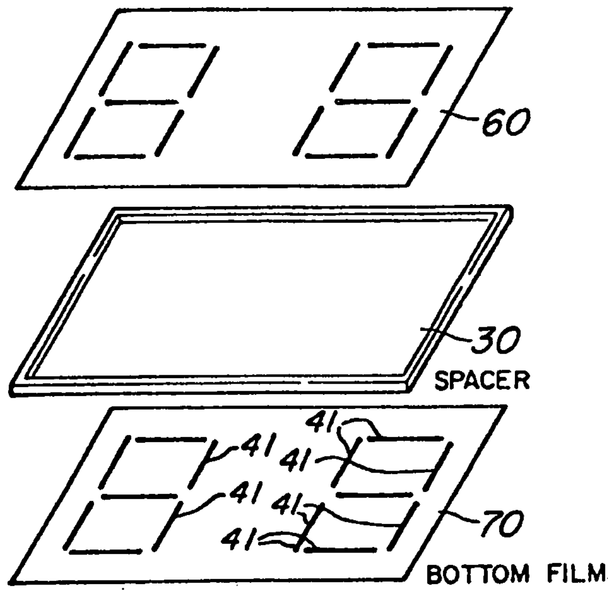

Fig.6

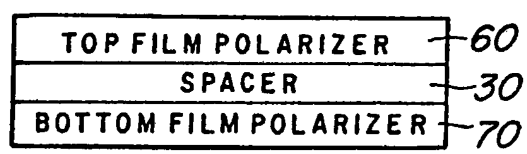

Fig.7A

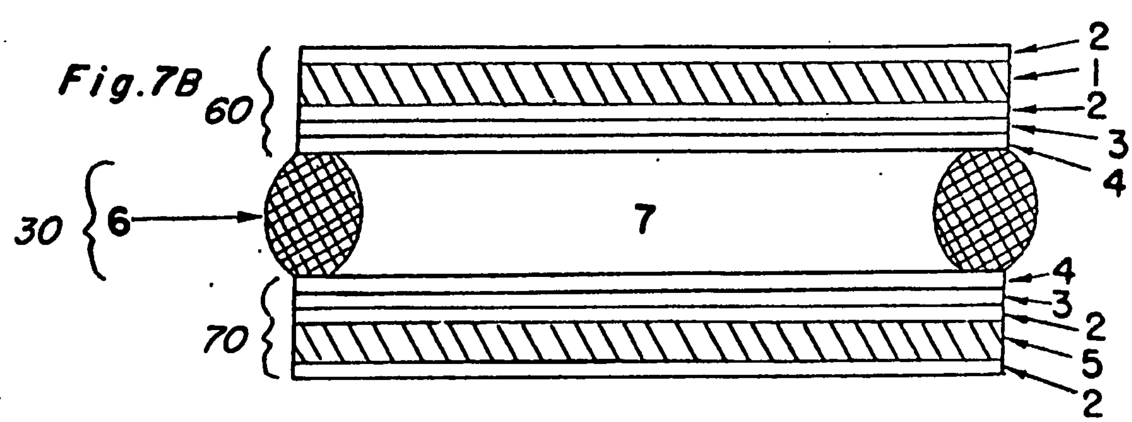

Fig.7B

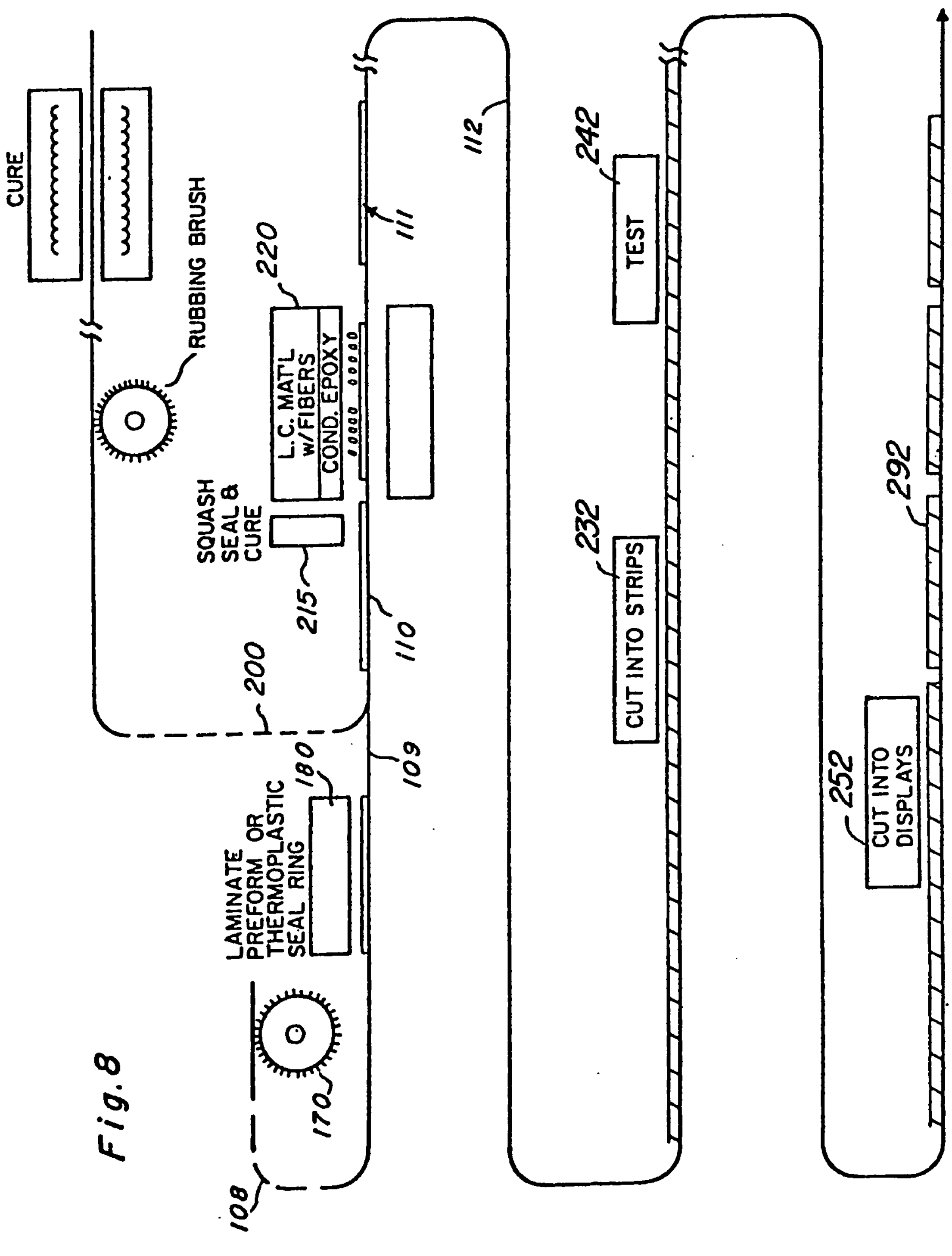
CURE
RUBBING BRUSH
220
L.C. MAT'L w/FIBERS
COND. EPOXY
111
112
242
TEST
SQUASH SEAL & CURE
215
110
200
232
CUT INTO STRIPS
292
LAMINATE PREFORM OR THERMOPLASTIC SEAL RING
180
109
252
CUT INTO DISPLAYS
170
108

Fig. 8

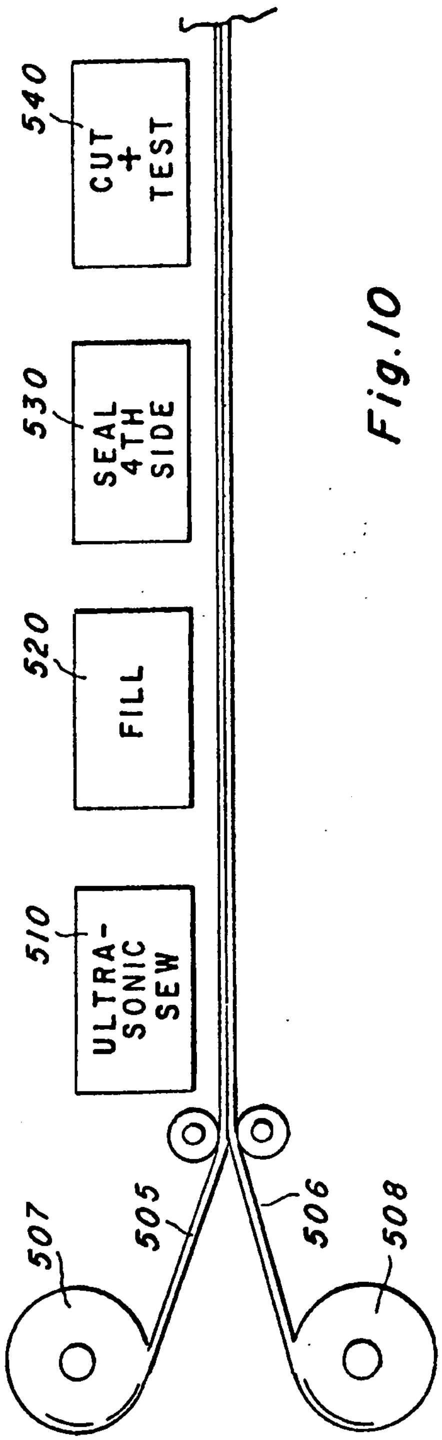
507
505
506
508
510
ULTRA-SONIC SEW
520
FILL
530
SEAL 4TH SIDE
540
CUT + TEST

Fig.10

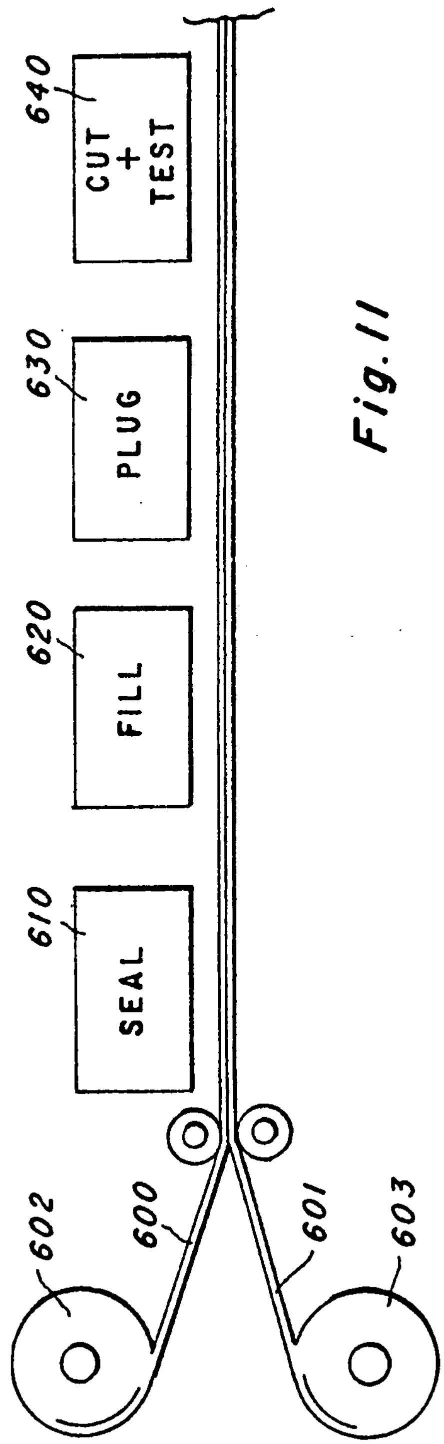
602
600
601
603
610
SEAL
620
FILL
630
PLUG
640
CUT + TEST

Fig.11

SPECIFICATION

Liquid Crystal Display and Fabrication Process

This invention relates to displays and more particularly to liquid crystal displays and an automated process of fabricating such liquid crystal displays wherein continuous strips of material are used, operated upon, and formed into a liquid crystal display package.

Basically, liquid crystal compositions are materials which exhibit reversible optical properties when subjected to an electric field. Normally the compositions are transparent to light, but in the presence of an electric field they scatter incident light. This characteristic has been extensively discussed in literature and will not be discussed in detail here. Further, exemplary liquid crystal compositions that are responsive to either D.C. or A.C. excitation voltages are well known.

Liquid crystal displays are known to operate in at least two basic modes, namely the reflective and transparent modes. The displays which are the subject of this invention are adaptable to either mode of operation. A reflective mode liquid crystal display device is comprised of a transparent electrode spaced from a second transparent electrode with the space between the two electrodes being filled by a liquid crystal composition. When an electrical bias is placed across these two electrodes the composition is subjected to an electric field which causes it to change its optical characteristics. This causes the contrast of the viewing plane formed by the reflective electrode to change in the region adjacent the portions of the liquid crystal composition which are subjected to the electric field. By shaping at least one of the electrodes to conform to the pattern or a portion of the pattern to be displayed a desired display pattern can be formed.

A transparent mode liquid crystal device consists of two transparent electrodes and a liquid crystal composition positioned therebetween. A light source is placed behind the liquid crystal display and selected regions of the composition are subjected to the influence of an electric field by applying an electric potential between the electrodes. The electric field causes the liquid crystal composition to scatter light. By shaping at least one of the electrodes to conform to a pattern or a portion of a pattern to be displayed the desired pattern can be formed.

Since, as described above the pattern displayed is determined by the shape of one or more electrodes, a liquid crystal display can be tailored to the desired application. Typical displays include the well-known seven segment display used for displaying number between 0 and 9 as well as the dot display in which the pattern to be displayed is formed on a series of selectively placed dots. The dot type display may be formed by designing both the front and back electrodes of a liquid crystal display to have closely spaced electrically insulated conductors and orienting the front and back electrodes so that the respective conductors are orthogonal. The dot is formed by applying about one half the voltage required to cause the liquid crystal composition to scatter light to each of the electrodes. A dot is formed in region where the two electrodes cross.

Conventional liquid crystal display fabrication utilizes conductively coated and patterned glass. Between the two processed glass pieces a liquid crystal material (for example a twisted nematic liquid crystal material) is introduced, and a sealant is then introduced to trap the liquid crystal between the processed glass pieces. The glass processing is comprised of utilizing a photolithographic method to selectively etch a conductively coated glass piece; and applying an alignment layer in the orientation necessary to effect a liquid crystal display. A second conductively coated piece of glass is similarly processed with a different electrode pattern and with an alignment layer oriented in a transverse direction to the alignment layer on the first glass piece. The first and second glass pieces are aligned and placed adjacent to and in contact with one another. The liquid crystal material is introduced between them, and a sealant is introduced between the glass pieces so as to trap the liquid crystal material in place. Finally, polarizers are aligned with and adhered to each of the first and second glass surfaces. The problems inherent in conventional liquid crystal display glass fabrication include incompatability with automated processing, necessitating extensive human handling at all critical stages of the process. Additionally, photolithographic etching limitations as to resolution exists with larger displays on glass.

Summary of the Invention

Production costs of liquid crystal displays are reduced by development of an automated fabrication operation, wherein raw materials may automatically be fed in as required, and package displays automatically fabricated. Additionally, cost savings may be realized by combining functional materials. Such a process is made feasible by utilizing a flexible, strip form for incoming and interim materials, so as conveniently to be able to roll them on reels for storage at any process step. Such a process could also be used to produce large area displays conveniently and at low cost.

A process embodying the invention for fabricating liquid crystal displays utilizes a continuous transparent film to which a conductive coating has been applied. Using photolithographic techniques a pattern is formed on the conductive film layer, and selective etching is accomplished to retain only the desired display pattern. A second continuous film is similarly processed with a complementary pattern being selectively retained, the two transparent films being separately processed. A liquid crystal and spacer material is interposed between the first patterned film and the second patterned film and sealed

between them. The resultant sealed structure is cut into strips of displays, tested, and cut into liquid crystal display unit modules.

Polarizer layers may be bonded to the outer surfaces of the first and advantageously polarized films may be used for the first and second film strips.

Brief Description of the Drawings

By way of example, embodiments of the invention will be described in greater detail with reference to the accompanying drawings in which:

Fig. 1 is an exploded schematic view of one embodiment of a display device fabricated in accordance with the present invention;

Fig. 2 is a side view of the display assembly shown in Fig. 1;

Fig. 3 is a partially schematic process flow diagram of a method for producing a conductively coated patterned film suitable for use in a process embodying the invention;

Fig. 4 is a top view of a film used in a preferred embodiment of the invention;

Fig. 5 is a partially schematic process flow diagram illustrating continuance of the process flow shown in Fig. 3, to produce individual display modules as shown in Figs. 1 and 2;

Fig. 6 is an exploded schematic view of an alternative embodiment of a display device fabricated in accordance with the present invention;

Fig. 7A is a side view of the display assembly shown in Fig. 6;

Fig. 7B is a detailed schematic of the display assembly of Fig. 7A;

Fig. 8 is a partially schematic process flow diagram illustrating the continuance of the process flow shown in Fig. 3 in producing the structures shown in Figs. 6 and 7;

Fig. 9 is a partially schematic process flow diagram of another embodiment of the invention for fabricating LCD display modules; and

Fig. 10 and 11 are partially schematic process flow diagrams of alternative embodiments of the sub-process of sealing and filling the liquid crystal display modules.

Detailed Description of the Invention

Referring to Fig. 1, an exploded schematic diagram of a liquid crystal display film module fabricated using an embodiment of the present invention is shown. It comprises, as better shown in Fig. 2, a sandwich stack of parallel layers which, in order from the top to bottom, are a polarizer film 10, a top electrode film 20, a spacer frame 30, a bottom electrode film 40, and a polarized transflector film 50. Liquid crystal material is sealed within the volume defined by the spacer frame 30. The top and bottom electrode films 20 and 40 have patterned thereon segments corresponding to the desired display pattern.

Referring to Fig. 2, a side view of the liquid crystal display module of Fig. 1 is shown with the subelements of the module in a preferred embodiment. Typical dimensions of a three and one half digit liquid crystal display film module, suitable for use as a watch display, are lengths of 0.850 inches (21.59 mm) width 0.55 inches (13.97 mm), and thickness of 0.020 inches (0.508mm), without the polarizers. Typical thicknesses for the polarizer 10 and polarized transflector 50 are 0.008 inches (0.203mm), for the top film 20 and bottom file 40 are 0.007 inches (0.177mm), and for the spacer 30 is 10 microns (10 micrometers).

Referring to Figure 3, process useful in carrying out the present invention to produce a structure as shown by Figs. 1 and 2 will be described. A reel 100 dispenses a film 101 into the input of the automated LCD film fabrication processing system. The film 101 is comprised of a continuous strip of transparent film. Optically clear films such as mylar, polyethelene, tri-phthalate, poly-carbonate, poly-vinylchloride, cellulose, triacetate, etc., could be used in this process. Each film material has its own advantages and disadvantages which must be balanced with production costs and fabrication compatibility. Ideally, the film should be isotropic, such as cellulose acetate butarate (CAB). However, this material is chemically very unstable, and is attacked by most organic solvents, acids and bases. It is however, conceivable to use CAB type films with some protective coatings which are chemically inert and electrically insulating. In general, the thickness of the film used may be varied from 0.001 inch (0.0254mm) to 0.050 inch (1.27mm), though based upon material and process limitations, application, and cost standpoints, a thickness in the range from .004 inch (.1026mm) to .010 (.254mm) would appear optimum. Transparency of typical films is greater than 90%. However, films of lower transparency may also be used. A transparent conductive coating covers the film 101. The transparent conductive coating, for example, indium oxide or cadmium stanate, or preferably indium oxide doped with tin oxide, is sputtered or evaporated onto the continuous film for electrically controlling the tilt angle of the liquid crystal molecules. It is important that the film should withstand the heat of evaporation and should not evolve any material to contaminate the evaporation or sputtering system. For these reasons, films containing excessive amounts of plasticizers are not generally recommended for use. A coating of a minimum thickness of 400 Angstroms and a resistivity of approximately 500 ohms/square area of surface, is typically used. The thickness of this coating affects the transparency of the resultant coated film and an optimization must be made between required transparency and resistivity. The incoming film 101, may suitable be in a roll having a width in the range of 12 inches (304.8mm) to 36 inches (914.4mm). To facilitate convenient handling of the near continuous film 101, as well as make possible the use of standard manufacturing and processing

equipment, the roll of film is preferably slit to a width of 35mm (1.378 inches) or 70mm (2.756 inches). Presently available slitting machines and punch dies may be used to facilitate processing of the film 101 through an automated assembly line (for example, in the embodiments set forth in Figures 3, 4, or 5). Figure 3 shows a section of cut and punched film 500. Punch holes 501 provide for feed guidance in the automated assembly line processing of the film.

Returning to Fig. 3, a film 111 is fed from a reel 110 into the automated assembly process for contact with the film 101. The film 111 is a photoresist material in a film form, but other convenient manners of applying a photoresist material to the film 101 are acceptable. The choice of photoresist material would depend upon the resolution required by the pattern geometry of the conductive electrodes to be formed, and the chemical inertness of the film 101 utilized. Either a positive or negative photo-resist may be used. The photoresist 111 may be comprised of indium oxide, cadmium stanate, Dupont Riston, etc. The resist 111 is fed into face to face contact with the conductive coating on the film 101, and is applied thereto so as to uniformly cover the film 101 with the photoresist 111. The resultant film compound 102 is then fed through an automated assembly line, for example by means of guide fingers extending up through punch guide holes such as guide holes 501 in film 500 of Fig. 4, and is fed to a pattern exposure station 120. Exposure station 120 is periodically enabled so as to expose the film 102 as it passes through to a patterned light energy field which exposes the photoresist film 111 of the compound film 102. The light pattern emitted from station 120 corresponds to the desired electrode graphical pattern to be formed from the conductive coating of film 101 of the compound film 102. The resultant exposed compound film 103 is fed forward through photoresist development station 130. Station 130 chemically activates regions of the photoresist film corresponding to the electrode pattern into a hardened material (for positive photoresist) impervious to an etchant solution to be used in subsequent processing steps. The hardened photoresist film compound 104 is fed forward to a conductor etching and photoresist removal station 140. The station 140 removes the non-hardened photoresist from film 104 by means of a chemical etchant in a controlled environment so as to remove the conductive coating from the surface areas of film 101 of compound film 104 which does not have a hardened photoresist protective surface layer upon it. Etching of the conductor layer may be carried out with stanate at room temperature in 50% HCL for 10 to 20 seconds. In most cases, depending upon the film 101 used, there may be a preferential orientation of the pattern for etching. A film compound 105, emerging from the station 140, now includes the desired electrode pattern formed of the conductive coating on the transparent film 101. Film 105 is fed forward so as to pass through a roller coat-blocking layer station 150. A roller coat blocking layer may be applied by one of a number of methods, wherein a film is deposited of a material which will be formed into an alignment layer to align the liquid crystal molecules in a homogeneous or homeotropic direction. Many types of material may be used for this purpose such as a polymer coating, e.g. polyvinyl alcohol, which is compatible with the automated film deposit process. A resultant film compound 106 has the polymer layer deposited on it and is fed from the station 150 to a station 160 where the deposited alignment layer is cured and fixed. The curing process layer to an energy source such as infrared or thermal heating. A cured film compound 107 is then fed from station 160 to a station 170, where a rubbing brush or other method of rubbing in a single direction is used to physically align the molecules of the cured polymer layer to form a rubbed alignment layer on a compound film 108. Alternately, SiO_2 deposition techniques may be used to form an oriented alignment layer without rubbing.

Referring to Fig. 5, the film 108 is fed to an adhesive application station 175, where an adhesive pattern of seal rings is applied to the film 108. Laminate preforms, thermoplastic seal rings, or other type adhesive or epoxy may be utilized to form the adhesive pattern. In a preferred embodiment of the invention, the pattern may be screen printed onto the film 108. However, any other method of forming an adhesive pattern on the film 108 may be used which is compatible with an automated sealing process. A film 109 emerging from station 175 is combined with a second film 200, the bottom film in a preferred embodiment. The film 200 is processed in a manner similar to film 108. Film 200 is conductively coated, etched, and alignment layer rubbed film similarly processed to film 108 but with a different pattern, suitably complementary to the pattern of film 108, and having an alignment layer direction transverse to the alignment layer direction of film 108 when the two films are brought adjacent each other with the electrode patterns on each of the film strips facing each other. The film 109 and the film 200 are brought adjacent each other with the electrode patterns on each of the film strips facing each other such that the respective electrode patterns on film 109 are opposite to corresponding electrode patterns on film 200, to define pairs of corresponding electrode patterns. The film 109 and the film 200 are then fed to a station 215 where the two films are sealed together to form a film compound 110. The combined film structure 110 is fed forward to station 220 where a liquid crystal material with fiber spacers is introduced between the top and bottom films. Additionally, in a preferred embodiment a conductive epoxy is introduced between the top film and the bottom film within the confines of the seal, to form an electrical connection between a contact of the bottom

electrode pattern and a contact of the top electrode pattern.

The film compound 110 with liquid crystal material and spacing means interposed between film 109 and 200 is then sealed to form a plurality of liquid crystal display units 111.

The film compound 112 containing the liquid crystal display units 111 is fed to station 230 where the film compound 112 is cleaned to prepare for the attachment of a polarizer and a transflector. The film compound 112 is fed to station 235 where a polarizer 240 is attached to the film strip 109 of each display unit 111 in parallel alignment with film strip 109, and a transflector 245 is attached to the film strip 200 to form liquid crystal display unit cell 113. The polarization directions of the polarizer 240 and transflector 245 may be in parallel or transverse alignment with the polarization direction of the alignment layers of film strips 109 and 200, respectively when attached to form cell 113. The polarizer 240 and transflector 245 may be film strips of polarizer material, or alternately may be other forms of polarizer material compatible with automated processing of near continuous film strips.

In a preferred embodiment, the resultant film cells 113 are fed to station 260 where the individual liquid crystal display unit with polarizer and transflector attached may be cut into parallel individual strips, each containing multiple cells 113 in parallel alignment. The cut strips are fed to station 270 where the liquid crystal display unit cells 113 are individually tested for functionality, and failed units are marked accordingly, such as by depositing an ink spot on the cell. The cut and tested strips are then fed to station 280 where each individual liquid crystal display unit cell 113 is cut into a separate module 290, which is the finished liquid crystal display module as depicted in Fig. 1. The display may be twisted nematic, sematic, cholosteric to sematic phase change, dye, dynamic scattering or other type.

Referring to Fig. 6, an exploded schematic diagram of a liquid crystal display film module fabricated using an embodiment of the present invention is shown. It comprises as better shown in Fig. 7, a sandwich stack of parallel layers which, in order from the top to bottom, are combined optical polarizer and top electrode film 60, a spacer frame 30, and a combined bottom electrode and optical polarizer film 70. Liquid crystal material is sealed within the volume defined by spacer frame 30.

Referring to Fig. 7A, a side view of the liquid crystal display module of Fig. 1 is shown with the subelements of the module in a preferred embodiment. Typical dimensions of a three and one half digit watch liquid crystal display film module are lengths of 0.850 inches (21.59mm), width 0.55 inches (13.97mm), and thickness of 0.020 inches (0.508mm). Typical thicknesses for the polarizer top film 10 and polarizer bottom film 30 subelements are 0.010 inches (0.254mm), and for the spacer 30 having a thickness of 10 microns (10 micrometers). Additionally, a transflector may be attached to the bottom film polarizer to allow backlighting.

Referring to Fig. 7B, the polarizer top film 60 comprises a first polarizer film 1 covered on both an upper and lower surfaces by a chemical and abrasion resistant coating 2, a transparent conductor coating 3 overlying the resistant coating 2 on the lower surface, and an alignment layer 4 with a first orientation direction overlying the conductor coating 3. The bottom film 70 comprises a second polarizer film 5 covered on both upper and lower surface by the chemical and abrasion resistant coating 2, the transparent conductor coating 3 overlying the resistant coating 2 on the upper surface, and an alignment layer 4 overlying the conductor coating 3. The spacer 30 comprises a frame of sealant 6; spacers included with liquid crystal material 7 interposed between the alignment layers 4 of the top and bottom films 60 and 70, respectively, also assist in maintaining the spacing between the films 60 and 70. A structure as shown in Figs. 6 and 7 may be fabricated using a system as shown by Figs. 3 and 8 with changes in the input materials as noted below.

The film 101 may have similar dimensions and should have the same characteristics as those previously noted and preferably be coated with an abrasion resistant coating of the siloxane type. The polarized film may utilize cellulose acetate butate (subject to the considerations previously mentioned), acrylic, cellulose, triacetate or polycarbonate. The film 101 should have a uniform direction of polarization and is provided with a transparent conductive coating for controlling the tilt angle of the liquid crystal molecules which film is coated with resist to form a film 103; the resist is hardened to form a film 104, and etched to form a film 105, a blocking layer applied to form film 106, cured to form film 107 and treated to form an alignment layer, producing the film compound 108 all as previously described with reference to Fig. 3. The direction of polarization of film 101 may be parallel or perpendicular to the alignment direction of compound film 108. The compound film 108 is treated and combined with a second film 200, as described with reference to Fig. 3, the polarization direction of film 200 being parallel or perpendicular to the alignment layer direction of the film 200, as required, and sealed to form liquid display units 111.

As shown in Fig. 8 the film compound 112 containing the liquid crystal display units 111 is fed to station 232 where the individual liquid crystal display units are cut into parallel individual strips, each containing multiple cells 111 in parallel alignment. The cut strips are fed to station 242 where the liquid crystal display unit cells 111 are individually tested for functionality, and failed units are marked accordingly, such as by depositing an ink spot on the cell. The cut and tested strips are then fed to station 252 where each individual liquid crystal display unit cell 111

is cut into a separate module 290, which is the finished liquid crystal display module as depicted in Fig. 6. This display may be twisted nematic, sematic, cholosteric to nematic phase change, dye, or other type of liquid crystal display.

Referring to Fig. 9, a preferred method of sealing the two strips of film material will be described. A compound film 308, processed in an identical manner described with reference to the compound film 107 of Fig. 3, is fed to an adhesive application station 380 where a ring of adhesive is applied to the compound film 308 to form a compound film 309. For example, a seal ring may be printed upon the patterned surface of the compound film strip 308 to bond the compound film 309 to a second similarly processed compound film strip 400.

Alternatively, other methods of precision adhesive application to the compound film 308 may be used at the station 380. The compound film strip 309 emerging therefrom is brought adjacent to the compound film strip 400, with the electrode patterns on the two strips, 309 and 400, facing each other such that the electrode patterns of the film strip 309 are positioned opposite respectively corresponding electrode patterns on the film strip 400 to define pairs of corresponding electrode patterns. As shown in Fig. 9B, the pairs of corresponding conductive electrode patterns are formed in rows across and columns along the length of each of the film strips 309 and 400, such that multiple rows of liquid crystal display units will be formed along the length of the film 309 and 400 when they are sealed.

The film strip 400 is comprised of a film processed in a manner similar to the film 200 as described with reference to Fig. 4. However, the etched conductive pattern of the film 400 is complementary to the etched conductive pattern of film 308. The film 400 is fed to a dispenser station 390, where liquid crystal material with spacer fibers is formed, for example, deposited, onto the conductively patterned surface of the film 400, to form the compound film 408. The film 408 is combined with the film 309 in the manner previously described, and fed to a station 395. If connection between the electrode patterns of the top and bottom films 309 and 400 is required, then a conductive epoxy is introduced at this point between the films. The resulting compound film is fed to station 340, where it is placed under pressure and is exposed to a curing process, such as described with respect to Fig. 3 station 160, for example, by heat and pressure, to form a plurality of liquid crystal display modules. The resultant film compound 310 is then fed to station 410 and cut into individual modules 411, which are tested, and marked according, such as described with respect to the test station 270 of Fig. 4 to form the finished product in the form of stacked layers as depicted in Fig. 2.

To form a structure as shown in Figs. 6 and 7, the film strips 308 and 400 are comprised of polarized films, processed in an identical manner to film compounds 109 and 200 of Fig. 8. In this case, the etched conductive pattern of film 400 is complementary to the etched conductive pattern of film 308 and the alignment layer direction of the film 400 is transverse to the alignment layer direction of film 308, respectively, when the two films are brought adjacent with the electrode patterns on each facing the electrode pattern on the other. Processing then continues as described with reference to Fig. 9.

Referring to Fig. 10, a partially schematic process flow diagram of another embodiment of the sub-process of sealing and filling with liquid crystal material the LCD modules is shown. A compound film 505, processed identically to the film 309 of Fig. 9A, is fed from reel 507 to station 510, where the film 505 is combined with a second film 506, the film 506 being identically processed to the film 400 of Fig. 9B, film 506 feeding from reel 508. The film 505 and the film 506 are brought adjacent to each other with the electrode patterns on each of the film strips facing each other such that the respective electrode patterns on film 505 are opposite to corresponding electrode patterns of film 506, to define pairs of corresponding electrode patterns. The adjacent films 505 and 506 are fed to station 510 where three sides of the electrode patterned pair are ultrasonically sewn together. The resultant sewn film compound is fed to station 520, where liquid crystal material is introduced into the one edge which was not sewn and the filled compound film is then fed to station 530, where the non-sewn edge is sealed, such as by epoxy. The resultant compound film contain multiple liquid crystal display modules defined by each sealed electrode pair, and this resultant film is fed forward to station 540 where each individual sealed electrode pair is cut into an individual liquid crystal display unit module, and the individual unit modules are tested.

Referring to Fig. 11, film 600, identical to the film 309 of Fig. 9A, is fed from a reel 602, and is brought adjacent to a film 601, the film 601 being identical to the film 400 of Fig. 9A, the film 601 feeding from the reel 603. The film 600 and the film 601 are brought adjacent to each other with the electrode patterns on each of the film strips facing each other such that the respective electrode patterns on film 600 are opposite to corresponding electrode pattern on film 601, to define pairs of corresponding electrode patterns. The adjacent films 600 and 601 are then fed to station 610 where each electrode pattern pair is completely sealed, for example, using epoxy, except that two fill-in holes are provided in the film 600 or in the film 601. The resultant compound film is fed to station 620 where a liquid crystal material, and spacer fibers if required, are introduced via the fill-in holes into the sealed electrode pair. The resultant film compound is fed to station 630 where the fill-in holes are sealed, such as with epoxy. The resultant film compound contains a plurality of liquid crystal display unit modules, which are fed

to station 640, where each individual liquid crystal display unit module is cut and tested as described above.

It will be appreciated that the embodiments of the invention described, readily permit the use of automated processing techniques. The basic film strips can be fed from supply reels, as can the conductive and resist layers in a continuous manner. The operations required to expose and develop the resist selectively remove the resist and etch the conductive layers, as well as carrying out the rubbing and curing operations all can be carried out automatically in timed relation. The materials required for sealing the films, the liquid crystal material and any filler material all can be automatically dispensed. Cutting of the processed units into individual modules, as well as testing and marking the modules also are susceptible of automatic operation and control. By such means, reliable display modules may be economically manufactured on a batch or continuous manner.

Claims

1. A liquid crystal display unit fabrication process comprising:

forming an alignment layer on respective first and second elongated strips of flexible transparent insulating film which have conductive electrode patterns thereon;

bringing the film strips adjacent each other with the electrode patterns on the two strips facing each other such that the respective electrode patterns on one strip are positioned opposite corresponding electrode pattern on the other strip, to define pairs of corresponding electrode patterns;

introducing liquid crystal material and spacing means between the two film strips and forming seals between the film strips such that the liquid crystal material is enclosed in respective volumes between said corresponding pairs of electrode patterns on the two film strips to provide a plurality of joined liquid crystal display units wherein adjacent molecules of the liquid crystal material are subject to alignment forces by the alignment layers, in each enclosed volume the two film strips being separated by a predetermined distance defined by said spacing means.

2. A process as recited in Claim 1, wherein the alignment layers have alignment directions such that the alignment layer on the patterned surface of the first film strip has an alignment direction transverse to that of the alignment layer on the patterned surface of the second film strip when the first and second film strips are positioned adjacent to each other with the electrode patterns on the two strips facing each other.

3. A process as recited in Claim 1 or Claim 2, wherein the transparent insulating film is a plastic material.

4. A process as recited in Claim 2, wherein the transparent insulating film is composed of mylar, polyethelene, tri-phthalate, poly-carbonate, polyvinylchloride, cellulose, triacetate, or cellulose acetate butarate.

5. A process as recited in any preceding claim, further comprising:

attaching polarizer means to the first film strip of each display unit forming a first surface of the enclosed liquid crystal display unit, in parallel alignment with the first film strip; and

attaching transflector means to the second film strip of each display unit to form a second surface of the enclosed liquid crystal display unit in parallel alignment with the second film strip.

6. A liquid crystal display fabrication process as recited in Claim 4, wherein the attached polarizer means and transflector means of each unit have polarization directions transverse to the respective alignment layer polarization directions of the first and second film surfaces.

7. A liquid crystal display fabrication process as recited in Claim 4, wherein the attached polarizer means and transflector means have polarization directions which are parallel to the respective alignment layer polarization directions of the first and second film surfaces.

8. A process as recited in Claim 1 wherein, the alignment layer on the first and second film strips are oriented in mutually transverse alignment directions, and wherein said film strips are optically polarized film strips.

9. A process as recited in Claim 8, wherein the film strips are plastic.

10. A process as recited in Claim 9, wherein the polarized film is acrylic or cellulose acetate butarate.

11. A process as recited in any of Claims 8—10, wherein said first and second optically polarized film have polarization directions that are respectively transverse to the first and second alignment directions.

12. A process as recited in any preceding claim, wherein the transparent insulating film is protected by chemically inert and electrically insulating coating.

13. A process according to any of the preceding claims, wherein the spacing means includes seal rings surrounding the respective electrode patterns on the patterned surface of the first film strip.

14. A process as recited in Claim 13, wherein the seal rings are screen printed onto the patterned surface of the first film strip.

15. A process according to any of the preceding claims, wherein the spacing means includes filler means in the liquid crystal material.

16. A process according to Claim 15, wherein the filler means comprises fibrous material.

17. A process as recited any of the preceding claims, wherein the first and second film strips have guidance means to facilitate automated handling.

18. A process as recited in Claim 17, wherein the guidance means comprise parallel rows of apertures on 35mm or 70mm wide first and second film strips, to facilitate production handling by automated film transport equipment.

19. A process as recited in any preceding claim, wherein:

said conductive patterns are formed in rows across and columns along the lengths of each of the first and second film strips such that multiple rows of liquid crystal display units are formed along the length of the sealed first and second films.

20. A liquid crystal display comprising:

first optical polarizer means with a first polarization direction having a transparent conductive electrode pattern upon one surface defining one half of an electrode display pair;

second optical polarizer means with a second polarization direction having a transparent conductive electrode pattern upon one surface, said conductive electrode pattern being complementary to the first polarizer means electrode pattern,

said second polarizer means positioned such that the electrode pattern of the second polarizer means is in face to face parallel alignment with the electrode pattern of the first polarizer means, thereby defining the electrode display pair,

said second polarization direction being transverse to the first polarization direction;

first alignment layer means to align adjacent molecules of a liquid crystal material, said alignment means oriented in a first alignment direction overlying the first polarizer means electrode pattern,

and second alignment layer means to align adjacent molecules in a liquid crystal material, said second alignment means oriented in a second alignment direction transverse to the first alignment layer direction, overlying the second polarizer means electrode pattern,

said liquid crystal material sealed between the first and second polarizer means and in contact with the first and second alignment layers.

21. A liquid crystal display as recited in Claim 20, further comprising:

a chemical and abrasion resistant transparent coating disposed on and covering all surface areas of the first and second polarizer means.

22. A liquid crystal display as recited in Claim 20 or Claim 21, wherein:

the first polarization direction is transverse to the first alignment direction,

and the second polarization direction is transverse to the second alignment direction.

23. A liquid crystal display as recited in Claim 20 or Claim 21, wherein:

the first polarization direction is parallel to the first alignment direction,

and the second polarization direction is parallel to the second alignment direction.

24. A liquid crystal display as recited in any of Claims 20—23, wherein the liquid crystal material is nematic.

25. A liquid crystal display according to any of Claims 20—24, wherein each optical polarizer means comprises a flexible plastic film.

26. A liquid crystal display comprising first and second flexible film strips enclosing liquid crystal material, sealed together and separated by a predetermined distance; each flexible strip having a conductive electrode pattern on the surfaces thereof adjacent the liquid crystal material; and wherein each electrode pattern is covered by an alignment layer operable to align adjacent molecules of the liquid crystal material in predetermined alignment directions.

27. A liquid crystal display according to Claim 26, wherein the alignment directions are transverse to each other.

28. A liquid crystal display according to Claims 26 or 27, wherein the flexible strips are composed of a plastic material.

29. A liquid crystal display according to any of Claims 20—28, wherein the liquid crystal material includes means for spacing the polarizer means by a predetermined distance.

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